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Icon Design Principles for Preschoolers: Implications Derived From Child Development

Shuhui Chiu*, Chorng-Shiuh Koong, Sa-Hui Fan

National Taichung University of Education, 140 Minseng Rd, Taichung, 403, Taiwan, R.O.C.

Abstract

To better design GUI for preschool users, this study suggests three icon design principles: the principle of obvious visibility, the principle of visual resemblance, and the principle of conceptual resemblance. The conceptual reasoning behind the proposed principles is borrowed from research areas of semiotics, picture-reading and neurodevelopment of children. These principles had also been applied to icon designs for the self-made story-authoring software, *MyStory*. With this application, the readability of the designed icons is investigated. Icon designs violating any proposed principles result in low readability. Five reasons for lower readability are proposed: unrealistic decorative designs, distorted written styles, experience void, overgeneralized association, and infrequently visible.

Keywords: Child development, Icon design, Interface design, Preschoolers, Story-authoring

1. Introduction

Graphical user interface (GUI) design has not only made computers more accessible to adults but also to children of early ages. One of the reasons why GUI has created wider and more possible access to computers for young users is its use of symbolic icons as indicators of computer commands. This assists the users to be able to operate technological tasks visually and to gain mastery in the realm of symbolic mentality (Kay, 1990). Specifically, the GUI design emphasis is on eliciting metaphors from real objects or concepts that the computer users already know well, so that the users can intuitively induct the

* Shuhui Chiu. Tel.: 011-886-04-22183856; fax: 011-886-04-22183400.
E-mail address: shuhui@ms3.ntcu.edu.tw.

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symbolic meanings of the icons and master different functions of computers (Blackwell, 2006). However, different users' interpretations may vary, and the variations may be extended beyond what the designers had originally expected. Only if, during the design process, the designers can put themselves in the shoes of the computer users, feel what the users feel, and ponder what the users are pondering, will the potential icons be possibly interpreted correctly by the users (Norman, 1999). Hence, some researchers suggest that during the process of designing computer icons for young children, some prospective users should be invited to participate in the design process to better explore their psychological modifications and interpretations (e.g., Druin, 2002).

There were two flaws found in the suggested children-participating design process despite the benefits given above. First, in such design process, the designers were usually too focused on the design itself to investigate the psychological modifications processed by the children or to even notice why the potential icons were successful (Whittaker, Terveen, & Nardi, 2000). Moreover, if the target users were preschoolers, communication between the designers and the participating users was somewhat restricted because of the limited language expressions of the youngsters. Hence, the developmental psychology of the youngsters needs to be considered (Sluis-Thiescheffer, Bekker, Eggen, Vermeeren, & de Ridder, 2011).

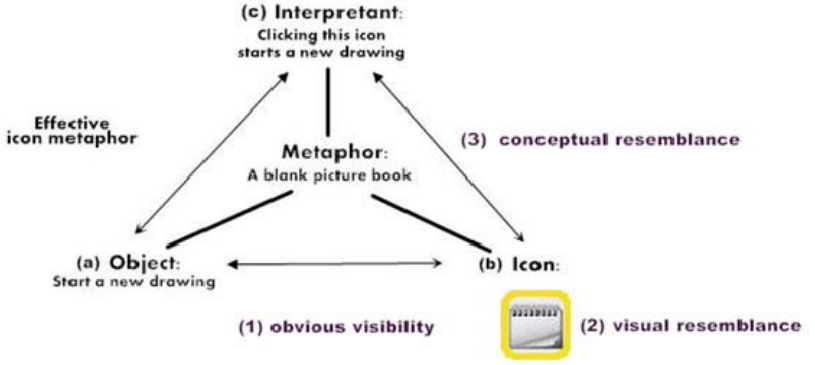
To solve the above problems of the GUI design for preschool users, this study has suggested a set of icon-design principles from the perspective of child development. The conceptual reasoning used to propose the design principles was borrowed from different research areas, such as semiotics, picture-reading, and neurodevelopment of children. This new set of principles has also been applied to icon designs for the self-made story-authoring software, *MyStory*. In addition, the readability of the designed icons has also been investigated in the current study. To explore the interpretations made by preschool users of the icons of *MyStory*, this study contained two phases of testing. The first phase focused on an exploratory-icon recognition test. Modifications of icons were made corresponding to the first test results. The second phase included a summative-icon recognition test to investigate the readability of the modified icons used in *MyStory*. Findings from the recognition ratios and from children's responses to our interview were elicited and suggestions were made.

2. Icon design principles for preschoolers

Peirce's triadic model is useful for comparing design intentions with perceived meanings. According to the Peircean triad, the interpretation of an icon metaphor involves three components: (a) an object, which is the abstract task; (b) the icon, which is the pictorial symbol used to stand for an object; and (c) the interpretant, which is the interpretation made by the users (de Souza, Barbosa & Prates, 2001). Based on this model, an icon is effective only when the interpretant of the user matches the object that the designer had intended with the icon. In line with the Peircean triad, the object and the interpretant shown in Figure 1 should agree. To reach such agreement, a proper icon design may be crucial. A good icon metaphor can bridge the two sides of the Peircean triad (e.g., *a*-*b* and *b*-*c*), so that the users can properly associate icons with meanings given by the designers. For the purpose of reinforcing connections of *a*-*b* and *b*-*c*, this study proposes a set of icon design principles: the principle of obvious visibility, the principle of visual resemblance, and the principle of conceptual resemblance.

2.1. Principle of obvious visibility

With insights contributed by developmental cognitive neuroscience, scholars found that the frontal lobes that related to *Executive Functions* (EFs) and short-term memory are relatively immature for children from age 3 to age 8 (Fusaro & Nelson, 2009). EFs allow adults to pay attention to relevant information on the interface while inhibiting irrelevant information. With immature EFs, younger children are not able to have a good command of attaining the information on the interface as adults do. For young children, out of sight usually means out of mind. Hence, it is not surprising for Gilut and Nielsen (2007) to see that school-aged children surfing the internet mainly interact with what was visible above the fold, and to suggest that designers should make icons look clickable with visual rollovers to serve as cues. In accord with the viewpoints of Gilut and Nielson, this study tries to suggest that icon design for child users should be compatible with the principle of obvious visibility in order to attract attention and to assist recall for young children. Thus, *a*-*b* in Figure 1 will agree. This viewpoint can be illustrated by the example of Figure 1. The designer chooses "a blank picture book" as the metaphor of



"starting a new drawing", and uses  as its icon. The icon should be able to attract the young users' attention.

Fig. 1. Three principles proposed to reach an effective icon metaphor

2.2. Principle of visual resemblance

Based on the framework derived from Picture Reading (e.g., Gattis, 2001), researchers of this study suggest that the users should receive both visual and conceptual cues via icons. These cues must be helpful in the retrieval of storage memories for recognition and understanding (Bauer, 2009). After the user receives visual cues provided by the icon, the icon's visual representation will preserve perceptual resemblance of what it represents to reactivate the neural network that represents the image. As a result, in Figure 1, the users can associate the icon with "a blank picture book". Noteworthy, using a concrete object as a metaphor does not guarantee the graphical image resemble the object. The graphical image of an icon must meet the principle of visual resemblance to be recognized.

2.3. Principle of conceptual resemblance

After the user recognizes the icon metaphor, he/she can then proceed with reading the conceptual cues provided. Similarly, a metaphor should be able to convey concepts and attributes resembling the object to reactivate the neural network that represents the concept. As in Figure 1, the drawing action associated with a blank picture must resemble the action of starting a new drawing, so that the long-term memory of the users can be activated to interpret messages delivered by the icons. Child users will be able to have *b*-

c agree easily by being introduced to picture books in advance. That is, the prior experiences of a user can help to store images and build up conceptual neural networks in the brain. The principle of conceptual resemblance is also in accord with the norms for meaningfulness and familiarity proposed in prior studies (McDougall, Curry, & Bruijn, 1999).

In summary, these principles emphasize that icons should be visually conspicuous to attract the attention of preschool users and resemble the visual features of metaphors, so that preschoolers can recognize them immediately. These tips also note that icons should also resemble the conceptual and functional features of the metaphors to simulate the appropriate association within preschoolers. To demonstrate the feasibility of the proposed three principals in explaining children's interpretations of icons, this study applies them to discuss the readability testing results for icons of a story-authoring software, *MyStory*. *MyStory* is briefly described in the following section.

3. The design of *MyStory*

3.1. The program design process

MyStory is a story-authoring program, which allows 3-6 year old preschoolers to imagine and tell stories of their own with digital photos and audio inputs. Storytelling serves as a critical role in children's development. Young learners tell stories about events they have experienced. In storytelling, children not only practice their commands of knowledge, but also need to take the listener's perspective into consideration (Hamilton & Weiss, 2005).

The program design process of *MyStory* involves requirement gathering, iterative program design, and users' feedback analysis. Requirement-gathering was performed through field observations and through a questionnaire survey. First, the social context in which children work was observed. Second, thirty-nine preschool teachers, with 3-18 years of teaching experiences, were asked to respond to a questionnaire about what children may need to operate well on a story-authoring program, and what teachers may request to integrate a story-authoring tool into teaching. The iterative program design process involved serious discussions and brainstorming. Members of the design team come from multiple disciplines, including early childhood education, computer science, and multimedia design. Besides referencing related theories, user requirements are the major concern. Users' feedbacks were gathered from the teachers and the child users through quantitative and qualitative surveys. In this study, only children's feedbacks were discussed. Children's feedbacks were gathered through an exploratory and a summative interface usability evaluation.

3.2. The icon and interface of MyStory

In practice, generally there were two teachers and thirty children in a preschool classroom, and only one computer in the story-authoring center. Roughly, two to three users may choose to enter the story-authoring center at one time and work cooperatively to create stories. Therefore, the interface design must fulfill the needs of multiple users at one time as well as children's desire to work with peers. Hence, the interface of *MyStory* incorporates multiple entrances for numerous child users (Figure 2a). A child may click on his/her numbered entrance and then enter a personalized interface with the child's name on the screen (Figure 2b). In *MyStory*, story authoring tasks are broken down into five easy steps as a scaffolding structure, including: selecting photos (Figure 2c), adding book covers, recording narratives for each photo (Figure 2d), selecting background music, and selecting an animation effect.

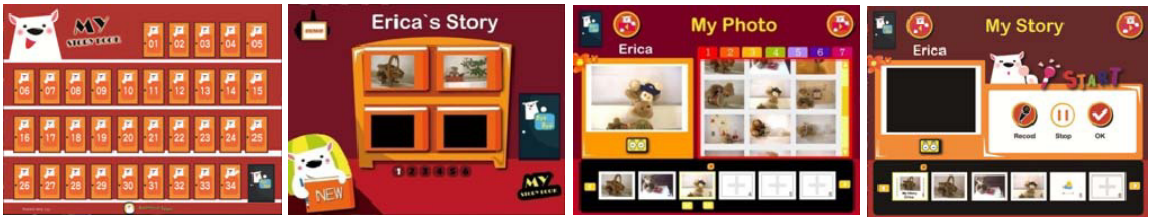


Fig. 2. (a) multiple entrances; (b) personalized interface; (c) photo selection; (d) audio recording

This study adopts the three principles proposed in this study to design icons. To comply with the obvious visibility principle, icons were animatedly designed and simple visual rollovers were added to serve as cues to young children that an icon is clickable. For example, the "door" icon was used as a metaphor of an entrance into the interface. When the icon is rolled over, the "bear" on the "door" would wave hands to attract the eyes of the preschoolers. To meet the requirement of visual resemblance, the graphical image of the "door" icon was composed of two visual features, a colored rectangle as the door per se and a small round dot as a door knob. These two images are often associated with the object of a "door" in real life. Also, in real life a door is often used as an entrance to another room which is in accordance with the principle of conceptual resemblance. Likewise, conceptually a "book" may be used to resemble a "story". Thus, books placed on the bookshelves symbolize a child's story created previously. A new book held and opened by a bear signifies starting a new story.

4. Icon readability tests

In this study, an interactive simulating interface prototype was designed after the exploratory icons had been completed for *MyStory*. The prototype was used on the preliminary test to first examine the readability of the exploratory icons, and then to gather feedback for modifications. After the icon modification was completed, a summative readability test on the interface icons was conducted. Because ongoing modifications were underway between tests, the number of tested icons was different on the two tests: 19 on the exploratory test and 22 on the summative test.

4.1. Participants

Nineteen kindergartners and 16 1st graders participated in the exploratory test. Their average age was 6.7 (*SD* = 5.1), and male children consisted of 64% of the total. The 1st graders were invited to participate in the exploratory test because they could articulate themselves more clearly. Articulated feedback would benefit the upcoming icon modifications. On the other hand, only kindergartners were invited to participate in the summative test since icon modifications had been completed at that moment. The number of the participants in the second phase was 20, and their average age was 5.5 (*SD* = .24), and male children consisted of 56% of the total.

4.2. Semi-structured icon readability tests

The methods of investigation on both exploratory and summative tests are identical. In a set-off space individual participant was directed by the testers to complete the process of composing a story step by

step. Tasks and listed questions were aimed at assessing the child's ability to identify icons. Examples of commands given by the testers are listed as follows:

- Now, let's start to create a story. Which button should we click?
- What should we do to choose a picture for our story? Where should we click?
- What should we do to choose a cover for this book?
- What should we do to move forward to the next step after we have selected the book cover?
- What should we do to record our story?

On both tests, the tester spent about 20 minutes introducing the software to the tested child. If the child identified an incorrect icon, the researcher would further interview the child to explore his/her possible reasoning.

4.3. Measure of readability

For each icon, the number of the participating children identifying it correctly was divided by the total number of the participant children as the recognition ratio. That is, icon readability is measured by whether the users can recognize the icon requested by the tester in this study.

4.4. Qualitative analysis

When children identified an incorrect icon, their reasonings were recorded and transcribed. Two researchers read the qualitative data and elicited the common patterns underlying children's reasonings. A third researcher was responsible for challenging the proposed patterns. The discussion continued until they reached consensus.

5. Results

5.1. Recognition ratio of icons

By comparing the quantitative results of both the exploratory and the summative tests, the researchers found that the recognition ratio of the less recognizable icons on the exploratory test reached a higher recognition ratio on the summative test after modifications. Results of the exploratory test showed that the recognition ratio of all icons ranged from .23 to .95 (M = .83, SD = .10). After modifications, the recognition ratio was raised to the range from .65 to 1.00 (M = .92, SD = .06). The four less recognizable icons, which had the recognition ratio lower than .75 of the exploratory test, included two concrete daily objects (TV and pencil), an abstract triangular symbol, and a set of digital figures. After modifications, the recognition ratios of both concrete and abstract icons were all significantly enhanced. Table 1 illustrates the graphical design of these four less recognizable icons on both the exploratory and the summative tests. Despite the fact that modifications of the icons did raise the average recognition ratios, results of the summative tests still show that there is room for improvement. In the following section, data of interviews with children provide further explanations.

5.2. Reasons for lower recognition ratios

According to the patterns elicited from the qualitative interview, there are five reasons why the icons are less recognizable by children: unrealistic decorative designs, distorted written styles, experience void, overgeneralized association, and infrequently visible. Examples will be exemplified below.

Table 1. The recognition ratios and graphical design of the less recognizable icons

Function of Icon		Demo	Bookshelf No.	Play	Edit
Exploratory test (*n*=35)	Icon				
	Ratio	.49	.57	.49	.23
Summative test (*n*=20)	Icon				
	Ratio	.95	.90	.75[a], .90[b]	.65

a: icons appear only when rolled over by a cursor; b: icons appear constantly on the preview window.

5.2.1. Unrealistic decorative designs

On the exploratory test, in the self-made software, *MyStory*, a TV was used as a metaphor for a user support video. Children could click on the TV button to watch a tutorial video. Seventeen percent of the participating children could not recognize the graphic as a TV because it had two extra "horns" (in the children's words) on its top surface. This indicated that a decoration inconsistent with the children's real-life experience might hinder recognition. After removing the unnecessary decorations which had no resemblance to the children's life experiences, it became easier (90%) for the participating children to choose the button when they were asked to seek a tutorial video clip.

5.2.2. Distorted written styles

In *MyStory*, stories made earlier by the participants were placed on the personal bookshelf interface. Children could click on the number underneath to browse through the multiple bookshelves. Fourteen participants were not able to recognize the symbols as numbers. Preschoolers first learning the numerical system may have a much more rigid scheme for its representation, and distorted numbers may hinder the assimilation process. After switching to a classical style, the recognition ratio reached to .90 on the summative evaluation.

5.2.3. Experience void

A previous experience void of conducting certain behaviors might hinder children from associating the metaphors with the real objects. For example, a triangle is used in the prototype to indicate "play" because it is an often-seen icon on audio or video tools, such as a CD player. Fourteen percent of the participating children expressed that they could not associate it with "play". The triangle metaphor could not be recognized by children because of their previous experience void of using audio or video tools. After modification, a concrete image of eyes was used instead to be associated with "look" or "play". This icon appears in multiple places on the interface. In the photo-selecting interface, this icon located on the preview window is consistently well-identified.

5.2.4. Overgeneralized association

The designers' overgeneralizing the experiences of adults regarding association as being the same for children might hinder children from associating the icons with the real objects. The prototype used a pencil as a metaphor to represent the "edit" command. On the exploratory test, children had trouble associating the metaphor with writing or editing. Eleven percent of the participating children could not

associate the metaphor with a real pencil because they said the shape of the pencil should be thinner and longer; some (23%) expressed that the pencil should be used for drawing but not for writing or editing. This may imply that the important features of how children perceive objects could be very critical in whether they could associate the metaphor precisely with real objects. Oftentimes, adults, including the designers, overgeneralize that adult experiences and the experiences of the children's world regarding association are compatible. This overgeneralization in design may confuse children.

5.2.5. Infrequently visible

After modifications, in the completed software program, a highlight would appear when children rolled over to the completed book (story) on the bookshelves. Children could simply click on the book to initiate the editing process. However, the recognition ratio was still low (.65). The possible cause may be derived from the children's responses such as "Oh! I forgot!" This response may indicate that some participants failed to roll the cursor over the completed books, so they did not spot the yellow highlight which served as a hint for initiating the editing process. Also, in the personal interface, to make the interface simple, the play icon "eyes" appears only when the cursor is rolled over to a specific book. Its recognition ratio (.75) is lower than that of locating stationary on the photo-selecting interface (.90).

6. Discussions

Icons on this study were designed and modified based on the three principles of obviously visible, visual resemblance, and conceptual resemblance. Results show that most of the completed icons could be recognized by the preschooler participants. Findings of this study indicate that failing to recognize the icons might be caused by violation of any the above principles. Principle violations will be discussed further in the following.

6.1. Violation of the principle of obvious visibility

To make the interface simple and clear, sometimes designers may make icons (e.g., the play command) or visual cues (e.g., the yellow highlight around the book) appear only when the participants roll over the icons with the mouse. However, the icons or the highlight sometimes do not show up because the participants have not attempted to roll the mouse over the screen. This is an example of violating the principle of obvious visibility in design. Gilut and Nielsen (2007) point out one of the importance of usability design strategies for children is that designers should make clickable items look clickable and provide rollover visual feedback. This echoes the principle of obvious visibility.

6.2. Violation of the principle of visual resemblance

In the design process, designers might try to shape the icons into a cartoon style, add redundant decorations (e.g., antennas on top of the TV) or twist their original outlook (e.g., distorted numbers) to make the icons more special. However, this design process may run the risk of blurring the visible features and hinder the participants from retrieving their existing image schemes to appropriately interpret the icons. It seems that sometimes the exterior beauty of the icons may hinder readability (Russo & de Moraes, 2003), and simplicity is the best policy in icon design (Rogers, 1989).

6.3. Violations of the principle of conceptual resemblance

Most metaphors used in this study were modified images from daily objects. An abstract symbol was adopted only when no concrete object could be found to represent the concept. Although concrete objects are more recognizable than abstract symbols (Blackwell, 2006), interpretations of concrete objects (e.g., pencil as metaphor for editing) are often restricted by the children's prior experiences. In addition, the children's interpretations of certain abstract symbols might differ significantly from those of adults. For example, in this study the preschooler participants were prompted by a triangular symbol to proceed to the next step, but they failed to associate it with the command "play". Children have to learn to understand the meaning of an abstract symbol (McDougall, Curry, & Bruijn, 1999). However, icon designers often overlook the familiarity property of an icon as an important determinant of its usability.

7. Discussions

By applying the Peircean triad relationship to define effective icons, this study suggests that the users need to connect the object with the interpretant to recognize and interpret correctly the icons. First, the principle of obvious visibility concluded in this study emphasizes presentation of the icons. Second, the principle of visual resemblance focuses on the graphical design of icons. These two principles reinforce the connection between the object and the icon. Finally, the principle of conceptual resemblance is more related to the choices of metaphors. This principle places an emphasis on reinforcing the connection between the icon and the interpretant. Finally, all of the above findings can be supported by development theories. Although there have been several studies proposing guidelines for designing websites or computer software for children (e.g., Gelderblom & Kotze, 2008; Gilut & Nielsen, 2007), very few of them focus on readability of icons. The principles concluded in this study might not answer all of the problems encountered in the process of icon design, but their simplicity might still assist designers to enhance the effectiveness of icons.

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